

## Validity of Maximum Heart Rate Prediction Equations for Children and Adolescents

Fabiana Andrade Machado<sup>1</sup> and Benedito Sérgio Denadai<sup>2</sup>

Departamento de Educação Física - Universidade Estadual de Maringá (UEM)<sup>1</sup> - Maringá, PR; Departamento de Educação Física - Universidade Estadual Paulista (UNESP)<sup>2</sup> - Rio-Claro, SP - Brazil

### Abstract

**Background:** There are no studies in the literature to validate equations that predict maximum heart rate (HRmax) in children and adolescents.

**Objective:** To analyze the validity of the HRmax predictive equations “220 - age” and “208 - (0.7 x age)” in boys aged 10 to 16 years.

**Methods:** A progressive maximal exertion test was carried out in 69 apparently healthy boys aged 10 to 16 years. The initial test velocity was 9 km/h, with 1-km/h increments every three minutes. The test was maintained until maximum voluntary exertion was achieved, considering HRmax as the highest heart rate attained during the test. The measured HRmax was compared with the values predicted by the “220 - age” and “208 - (0.7 x age)” equations, using ANOVA for repeated measures.

**Results:** The mean values of HRmax (bpm) were: 200.2 ± 8.0 (measured), 207.4 ± 1.5 (“220 - age”) and 199.2 ± 1.1 (“208 - (0.7 x age)”). The HRmax predicted by the “220 - age” equation was significantly higher ( $p < 0.001$ ) than the measured HRmax and the HRmax predicted by the (“208 - (0.7 x age)”) equation. The correlation between the measured HRmax and age was not statistically significant ( $r = 0.096$ ;  $p > 0.05$ ).

**Conclusion:** The “220 - age” equation overestimated the measured HRmax and was not valid for this population. The “208 - (0.7 x age)” equation was valid for this population, showing results that were quite similar to those of measured HRmax. Future studies with larger sample sizes can verify whether the HRmax does not depend on age for this population, a situation in which the constant 200 bpm value would be more appropriate for HRmax. (Arq Bras Cardiol 2011; 97(2) : 136-140)

**Keywords:** Heart rate; child; adolescent; heart/physiology.

### Introduction

Heart rate (HR) is considered an easily measurable physiological variable, being routinely used to evaluate cardiovascular response during exertion and recovery<sup>1,2</sup>. Maximum heart rate (HRmax), in turn, is considered one of the criteria to assess maximum exertion in exercise tests<sup>3,4</sup> and is broadly used when prescribing exercising intensity<sup>4-6</sup>.

HRmax can be directly determined, usually with progressive maximal exertion protocols or indirectly, with the help of predictive equations that constitute a low-cost and easy-to-apply method of determining it<sup>1,7,8</sup>.

Among the several equations proposed to predict HRmax, the most widely known is the equation “220 - age”<sup>9,10</sup>, which is curiously of unknown authorship, although it is very often

cited as being the work of Karvonen et al<sup>11</sup>, although the work carried out by these authors did not involve the creation of this equation<sup>7,10,12,13</sup>. Another equation worth mentioning is “208 - (0.7 x age)” proposed by Tanaka et al<sup>4</sup>, which was developed in a meta-analysis study, after collecting data from the literature on 18,712 subjects.

The main characteristic of these and other formulas used to predict HRmax is that all of them consider that the variable decreases with age<sup>14</sup>. Although this decrease is a general consensus for healthy adult men and women, it might not be true for children and adolescents, and even if it is, this decrease must be measured for this specific population, considering that the decrease rates of most equations was determined for a broad age range that only included children and adolescents in some cases<sup>9,15,16</sup>.

Thus, considering to the importance of HRmax knowledge, so that a child or adolescent does not undergo training at an intensity that is neither appropriate nor planned and considering the lack in the literature, as far we know, of studies validating these two HRmax prediction equations for this population, the objective of the present study was to analyze

**Mailing address:** Fabiana Andrade Machado •

Av. Colombo, 5790 - Bloco M06 - Depto. Educação Física - Universidade Estadual de Maringá - 87020-900 - Maringá, PR - Brazil

Email: famachado@uem.br, famachado\_uem@hotmail.com

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the validity of the two HRmax prediction equations - "220 - age" and "208 - (0.7 x age)" - in boys aged 10 to 16 years.

## Methods

### Population

Sixty-nine apparently healthy and active boys aged 10 to 16 years were enrolled in this study. The mean values  $\pm$  Standard Deviations (SD) of age, height and body mass were:  $12.6 \pm 1.5$  years;  $152.7 \pm 13.1$  cm;  $47.3 \pm 14.1$  kg, respectively; the age median (interquartile interval) was 12.1 years (11.4 - 13.8). Age was calculated centesimally, considering the birth date and the date when the test was performed. None of the participants participated in regular training programs. All procedures used in the study were previously approved by the local Research Ethics Committee. Participation was voluntary, with no bonus or onus for the subjects. Before the tests were performed, the children's parents or tutors were informed of all the procedures the children would be submitted to and signed the Free and Informed Consent Form regarding test participation.

### Maximal effort exercise test

Prior to the exercise test on a treadmill, the participants visited to lab for an ergometer adaptation session and also to have anthropometric measurements (body mass and height) taken. The progressive maximal exertion test was carried out on a multiprogrammable treadmill (Inbrasport Super ATL, Porto Alegre, Brazil).

After a three-minute warm-up at 5 km/h, the test was started at 9 km/h, with 1-km/h increments every three minutes. Constant inclination was maintained at 1% throughout the test. Heart rate (HR) was constantly monitored using a heart rate monitor (Polar Vantage XL). The test was maintained until voluntary exhaustion was attained and the participants were verbally encouraged to keep the test going for as long as possible. Maximum heart rate (HRmax) was defined as the highest HR achieved during the test<sup>4</sup>, being considered attained (valid) only when signs of intense exertion (hyperpnea, facial flushing, irregular steps) were observed<sup>17</sup>.

### Statistical analysis

Data are presented as means  $\pm$  standard deviations (SD) for all measured variables. The methods were compared using ANOVA for repeated measures with Bonferroni post hoc test. One-way ANOVA was used to compare the HRmax measured between age ranges. Pearson's correlation coefficient was used to correlate the measured values with the predicted ones of HRmax, as well as to verify the association between age and measured HRmax.

Bland-Altman analysis<sup>18</sup> was used to calculate the limits of concordance between the measured HRmax and the that predicted by age; the level of significance was set at  $p < 0.05$ .

## Results

Table 1 shows the measured and predicted values of HRmax for boys aged 10 to 16 years. The values

demonstrated by the "220 - age" equation were significantly higher ( $p < 0.001$ ) than the measured values and those estimated by the "208 - (0.7 x age)", according to the ANOVA for repeated measures with Bonferroni *post-hoc* test. The correlation between the measured HRmax and the values predicted by the two equations was not statistically significant ( $p > 0.05$ ), showing the same coefficient of correlation for both equations ( $r = -0.096$ ).

Figure 1 shows the mean values  $\pm$  SD of HRmax for the different age ranges. One-way ANOVA did not show any significant different ( $p > 0.05$ ) between the age ranges. The correlation between the measured HRmax values and age was not statistically significant ( $r = 0.096$ ;  $p > 0.05$ ). The absence of a tendency toward the increase or decrease of HRmax with age was observed visually. This was corroborated by the correlation between these variables, which was not statistically different from zero. HRmax variability for the several age ranges, represented by the SD in Figure 1, did not show any tendency toward increase or decrease with age, either. Figure 1 also shows the high SD values observed, in which the lowest and the highest values were 5.1 and 9.0 bpm for the age ranges of 13-14 and 14-15 years, respectively.

Figure 2 shows the dispersion charts of measured HRmax values in the sample. It is noteworthy the high dispersion of data corroborated by the high SD shown in Table 1 for measured HRmax. It can also be observed that the values predicted by the "220 - age" equation, represented by the dashed line, show a tendency toward HRmax overestimation. Additionally, the values predicted by the "208 - (0.7 x age)" equation, represented by the dotted line, seem to be better adjusted to the measured HRmax mean.

The analysis of concordance between the measured HRmax and that predicted by the equations showed as bias (difference between the means)  $\pm$  SD of differences:  $7.1 \pm 8.3$  bpm ("220 - age") and  $-1.1 \pm 8.2$  bpm ("208 - (0.7 x age)"). It is worth mentioning the high bias of 7.1 bpm demonstrated by the difference between the means of values predicted by the "220 - age" equation and the measured HRmax values, which is in agreement with the overestimation of HRmax.

## Discussion

The objective of the present study was to analyze the validity of two predictive equations for HRmax, "220 - age" and "208 - (0.7 x age)", in boys aged 10 to 16 years. The main finding was that the "220-age" equation overestimated HRmax values on average, thus demonstrating that it is not valid for

**Table 1 - Values of measured and estimated HRmax for boys aged 10 to 16 years (n = 69)**

HRmax	Mean $\pm$ SD
Measurement (bpm)	200.2 $\pm$ 8.0*
"208 - (0.7 x age)" (bpm)	199.2 $\pm$ 1.1*
"220 - age" (bpm)	207.4 $\pm$ 1.5

*p < 0.001 in relation to 220 - age; HRmax - maximum heart rate.*

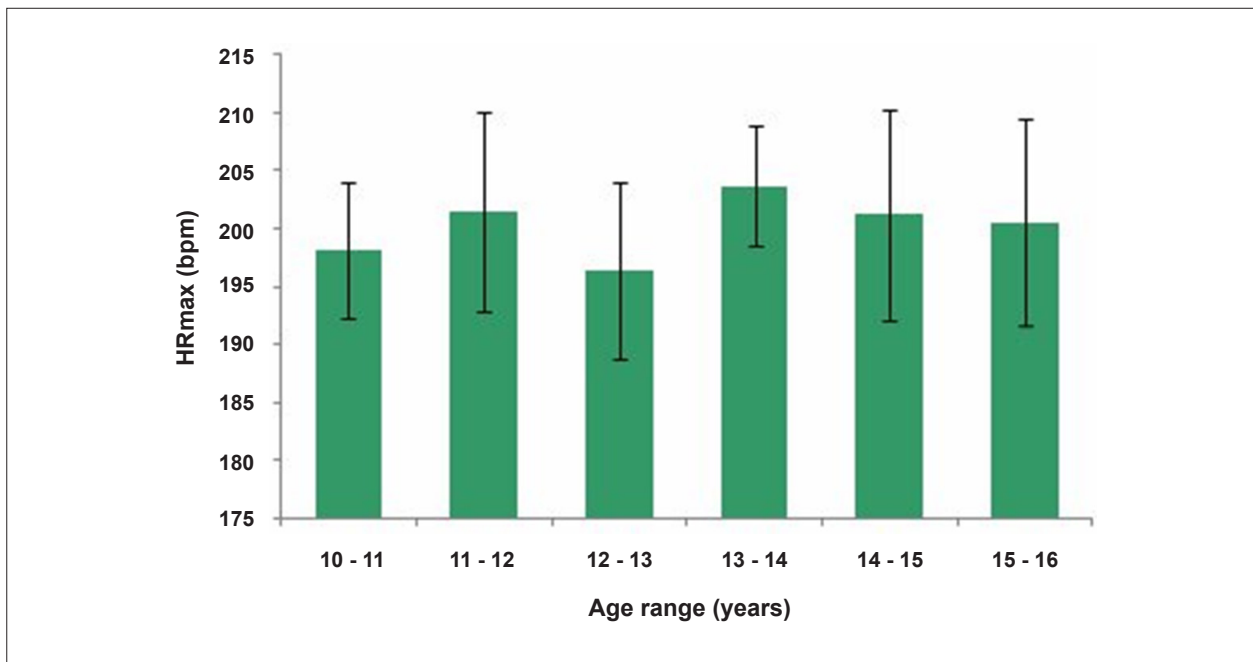


Figure 1 - Mean values  $\pm$  SD of measured HRmax for the different age ranges ( $n = 69$ ). There was no significant difference ( $p > 0.05$ ) between the age ranges.

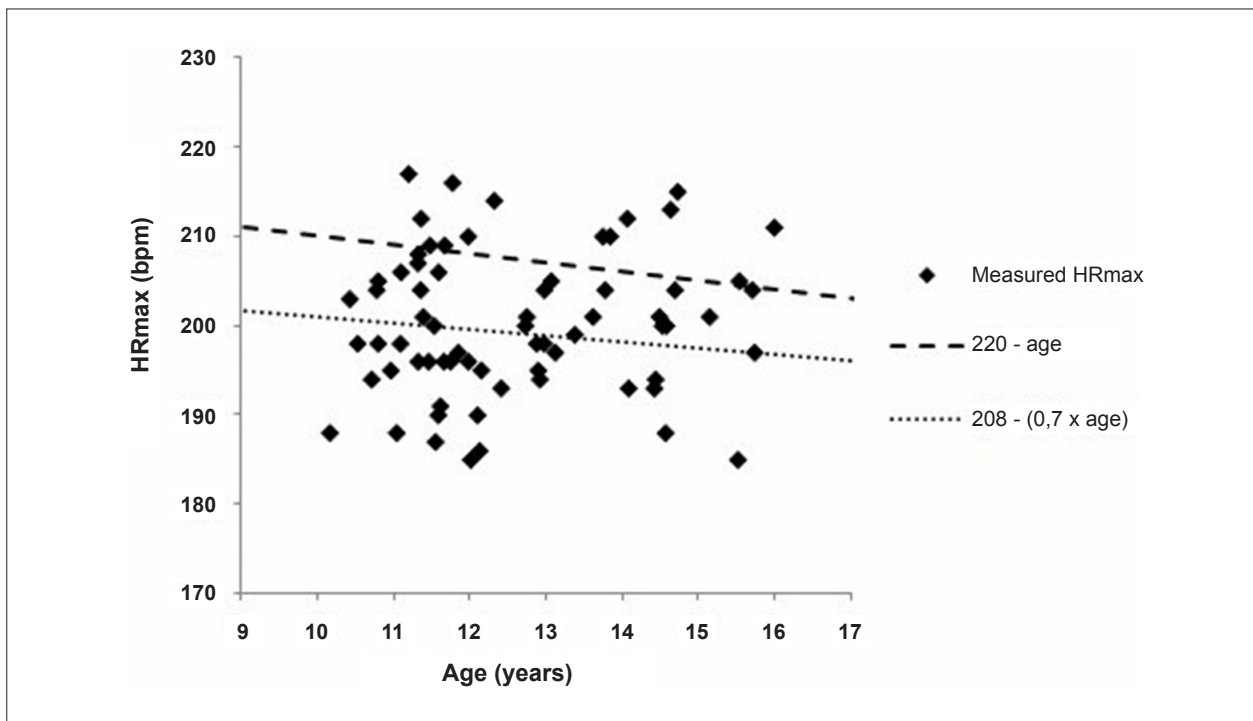


Figure 2 - Dispersion chart showing values of measured HRmax of the subjects ( $n = 69$ ). The dotted line represents the values predicted by the equation "208 - (0,7 x age)".

this population, whereas the "208 - (0,7 x age)" equation showed to be valid for this pediatric population. Moreover, we verified that HRmax was independent from age for this specific population, although it is important to emphasize that the studied sample ( $n = 69$ ) does not allow definitive conclusions to be drawn regarding this absence of association.

According to Almeida et al<sup>19</sup>, predictive equations are valid when applied to populations with characteristics that are similar to those of the sample for which the equation was developed. Hence, although broadly applied, the "220 - age" equation requires the samples for which it was generated, considering the author remains unknown as well as the age

range used when it was created. Regarding the “208 - (0.7 x age)” equation, it was generated by the linear regression of 18,712 subjects, especially between ages 20 and 70 years.

Table 1 showed that the mean value obtained with the “220 - age” equation was significantly higher ( $p < 0.001$ ) than the measured values and those estimated by the “208 - (0.7 x age)” equation. Therefore, the “220 - age” equation overestimates, on average, HRmax values. When applying the “220 - age” equation, one can verify that the predicted HRmax linearly decreases from 210 bpm at 10 years to 204 bpm at 16 years, overestimating the mean value of measured HRmax of 200.2 bpm throughout the age range 10 to 16 years. This can be verified visually in Figure 2. Contrarily to the “220 - age” equation, there was no significant difference ( $p > 0.05$ ) between the values predicted by the “208 - (0.7 x age)” equation and the measured values. The values predicted by the “208 - (0.7 x age)” equation decrease from 201 bpm at 10 years to 196.8 bpm at 16 years of age, showing values that are above (age < 11.1 years) and below (age  $\geq$  11.1 years) the mean of 200.2 bpm of the measured HRmax.

Figure 1 showed there was no significant difference ( $p > 0.05$ ) among the several age ranges for the measured HRmax. This absence of difference was corroborated by the fact that the correlation between the measured HRmax and age was not statistically significant. Therefore, the present study does not allow us to affirm that HRmax decreases with age in the studied population. Although the sample was not small ( $n = 69$ ), it does not allow us to draw definitive conclusions regarding the absence of association between HRmax and age.

Another interesting point demonstrated by the results was the high HRmax variability across the several age ranges, which was represented by the SD. This high SD showed no tendency toward increase or decrease with age, either. Both Figure 1 and Figure 2 show this high SD pattern for HRmax. It is noteworthy the fact that not only the measured HRmax showed a high SD, of around 8 bpm, but the difference between the means (bias) of predicted and measured values also showed an equally high SD.

These values are in accordance with the literature, which reports a standard deviation value of 10 bpm for the predicted HRmax values<sup>4,10</sup>. When the bias and the SD of the difference between the predicted and measured HRmax values are analyzed, one can observe a broad limit of agreement for 95% of cases between measured values and those predicted by the “220 - age” (-9.5 to 23.7 bpm) and by the “208 - (0.7 x age)” equations (-17.5 to 15.3 bpm), which can result in errors of up to +12% and -9%, respectively, considering the mean HRmax of 202.2 bpm. Therefore, one can conclude that the high variability of HRmax is the main limiting factor for its prediction.

## Conclusion

Based on these results, we conclude that the “220 - age” equation is not valid and appropriate for children and adolescents, as it overestimated, on average, the HRmax values for boys at the age range of 10 to 16 years. The “208 - (0.7 x age)” equation, in turn, showed results that were quite close to those of the measured HRmax and can be considered a valid equation for this pediatric age range. Moreover, if the age range is really independent from age for boys at this age range, which can be verified in future studies with larger sample sizes, the constant value of 200 bpm can become the most appropriate value for HRmax in this population.

## Potential Conflict of Interest

No potential conflict of interest relevant to this article was reported.

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## Study Association

This study is not associated with any post-graduation program.

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